Center for Biosecurity of UPMC

# After Fukushima: Managing the Consequences of a Radiological Release

Final Report – March 2012

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## Outside the Fence Issues: Increasing Resilience and Protecting the Public

Even amidst the devastation following the earthquake and tsunami in Japan that killed more than 20,000 people, it was the accident at the Fukushima Daiichi nuclear power plant that led the country's Prime Minister, Naoto Kan, to fear for "the very existence of the Japanese nation."

While such low-probability, high-consequence releases have been rare throughout the operating histories of existing nuclear power plants, the growing number of plants worldwide increases the likelihood that such releases will occur again in the future. Nuclear power is an important source of energy in the U.S. and will be for the foreseeable future. Accidents far smaller in scale than the one in Fukushima could have major societal consequences. Therefore, our purpose is to offer recommendations for policy and actions to ensure U.S. preparedness for managing nuclear accident consequences to reduce public exposure to radiation.

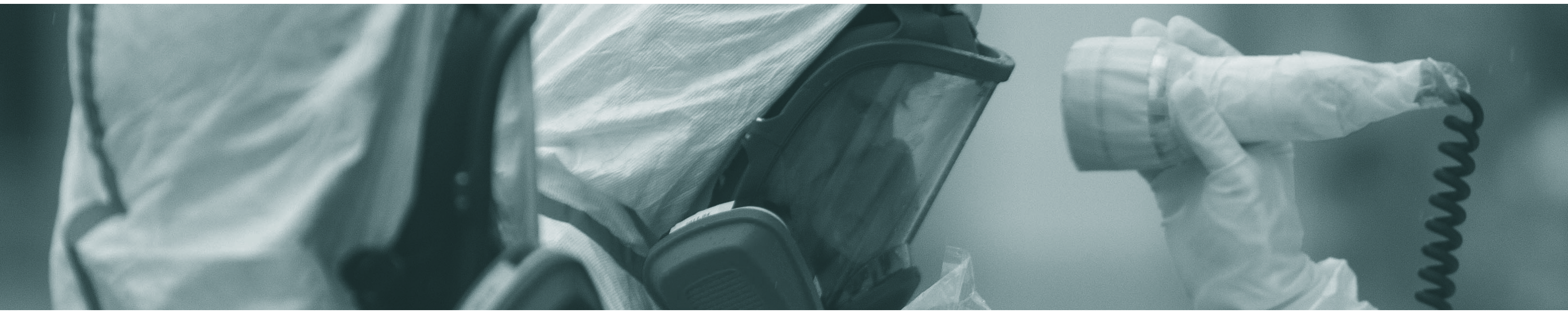
Given the extensive, ongoing Nuclear Regulatory Commission (NRC) and industry assessment of nuclear safety and preparedness issues, the Center's review was confined to offsite policies and plans intended to reduce radiation exposure to the public. This project was conducted and funded by the Center, in keeping with our longstanding mission to address pressing national policy challenges in homeland security and disaster preparedness.

## Mission

The mission of the Center for Biosecurity's *After Fukushima* project is to assess U.S. policies and plans for consequence management to reduce public exposure to radiation following a nuclear power plant accident and offer recommendations for strengthening those efforts.

## Analysis and Workshop

The Center reviewed the events surrounding the response to the Fukushima Daiichi nuclear power plant accident in light of current U.S. government policies and practices, and performed a comprehensive review of the published literature and key U.S. government documents. We then identified and interviewed more than 90 domestic and international experts in federal, state, and local governments, industry, and academia. Interview findings informed a working group meeting that convened 20 experts. The following represents the key issues, findings, and recommendations based on the synthesis of the results from the Center's efforts.



# ISSUES

## Issue 1: Emergency Planning Zones and Protective Action and Guidelines

Following the Fukushima Daiichi accident, the Japanese government concluded that the country's existing framework for offsite emergency response—the Emergency Planning Zone (EPZ) structure—proved inadequate to guide evacuation decisions. Japanese officials have since reevaluated the EPZs and are planning to expand the size of planning zones to account for large-scale contamination events, with the expectation that such changes will improve timely decision making during a crisis. In the U.S., each nuclear reactor is surrounded by 2 circular planning zones: the Plume Exposure Pathway EPZ, covering a 10-mile radius around the reactor, and the Ingestion Exposure Pathway EPZ, which encompasses a 50-mile radius surrounding each reactor. Within these areas, state and local governments take predetermined specific preparedness precautions, including emergency exercises, community-wide public education programs, and possibly the predistribution of potassium iodide (KI).

Protective Action Guidelines (PAGs) were developed by the U.S. EPA to help state and local authorities make radiation protection decisions. The PAG manual currently provides advice for the early and intermediate phases of an accident based on levels of anticipated radiation exposure. The U.S. PAG manual differs from protective guides used by the international community, known as Operational Intervention Level (OIL), which are defined as the values of environmental measures of radiation, like radiation dose measurements, above which specific actions should be taken in emergency situations. OILs differ from PAGs in that they do not depend on projected dose calculations. Instead, they recommend actions based on real-time measurements, often using on-the-ground field measurements, possibly allowing for a faster response. The U.S. should reevaluate the relative balance of PAGs and OILs used in response planning to a nuclear power plant (NPP) radiological release given the disruptions to the radiation monitoring systems witnessed in Japan.

## Issue 2: Potassium Iodide (KI) Policy

Potassium iodide (KI) is an over-the-counter medical countermeasure that can diminish the uptake of radioactive iodine by the thyroid gland and prevent thyroid cancer in children and developing fetuses. That KI has no value in protecting adults from cancer is well known by professionals and backed by scientific data.

U.S. federal policy recommends that states consider stockpiling and distributing KI as an adjunct to evacuation, which is the single most important protective measure available. Of 35 U.S. states that lie within the 10-mile EPZ of a nuclear power plant, 24 states predistribute KI as part of their emergency planning, and 9 do not. The experience with Fukushima provided some foreshadowing of possible U.S. demand for KI: As the plume of radioisotopes released from the Japanese power plant blew across the Pacific, many in the U.S. began to demand KI.

## Issue 3: Communications and Public Health Education

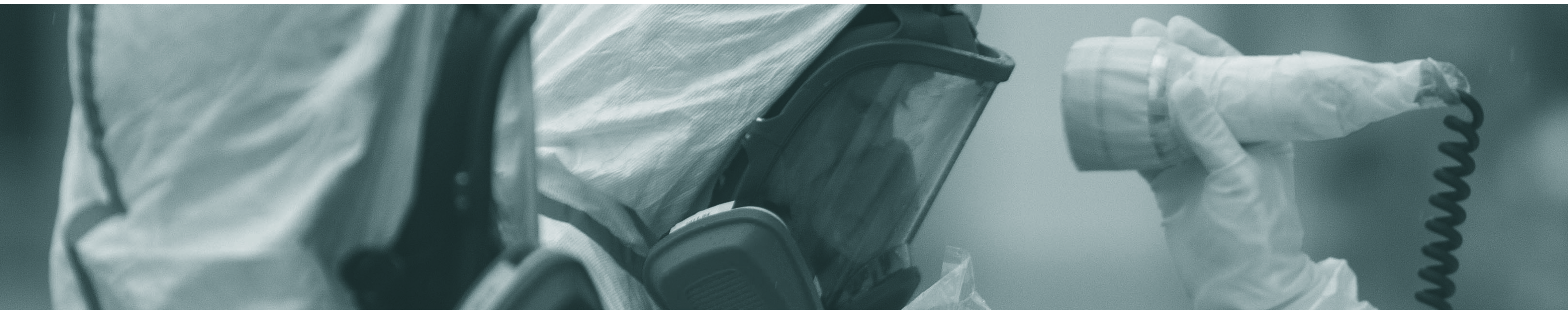
Ionizing radiation ranks near the top of the public's list of most feared threats. When a mass radiation event occurs, the public fear factor and low baseline knowledge about radiation create a major communications challenge. Federal communication efforts are further complicated by the need to coordinate information and messages from many agencies. The CDC, DOE, EPA, FEMA, HHS, NRC, and the White House were all included in the domestic response to the Fukushima accident. In contrast to the nuclear power plant accidents at Three Mile Island and Chernobyl, the Fukushima Daiichi accident has highlighted the new challenges of communicating with the public in the "information era" of 24-hour news cycles and social media outlets.

In the absence of consistent, trustworthy messaging from government authorities, members of the public may act in ways that put them in harm's way. Without guidance from the government, residents of the town of Namie in Fukushima prefecture evacuated north, into the plume, believing that the winter winds would be blowing south. In later phases of the accident, the Japanese government struggled to communicate the relative risks of radiation exposure as residents of contaminated areas returned to their properties. Radiation education has since become a part of elementary education; the Japanese government has distributed textbooks to schools throughout the affected region.

## Issue 4: Reentry and Recovery Policy

Prior to the Fukushima accident, planning for nuclear accidents in Japan had not taken into account the possibility of wide-scale contamination, major socioeconomic impact, and the possibility that large numbers of people would be displaced for extended periods of time, and perhaps indefinitely. The experience with that accident has raised questions about recovery from mass radiological events in which the health effects of residual ionizing radiation can be less threatening than the enormous socioeconomic impact of widespread contamination itself. The challenge is to define the acceptable level of post-accident population risk from radiation exposure.

Twenty years ago, the EPA published the PAGs as the official decision-making document to be followed during a radiological emergency. The PAGs establish principles for early and intermediate-phase response, but the agency deferred writing its chapter on the late phase, or recovery phase, to a later date. In January 2011, the EPA distributed a "significantly revised version" of the late-phase PAGs to the interagency working group for review. Until that review is completed and late-phase PAGs are published, there will not be clear federal policy for recovery and reentry after a nuclear accident.



# RECOMMENDATIONS

## 1. The U.S. should evaluate the adequacy of current Emergency Planning Zones.

In light of the Fukushima experience, the U.S. EPZ system should be carefully assessed to determine the following: Are planning zone distances sufficient to accommodate the potential radiation hazards posed by multiple units of a power plant, spent fuel storage, and the possibility of extended releases? Is the existing decision-making process during plant emergency conditions sufficiently timely and dynamic to be effective for conditions identified at Fukushima? Do we have sufficiently robust radiation measurement and modeling systems in place to monitor radiation threats in the aftermath of a large-scale accident? Would those systems still be functioning despite large-scale power loss or other disruption? Do current nuclear plant safety goals adequately reflect the socioeconomic impact of a wide-scale contamination event? Answers to these questions should guide future evaluations of U.S. EPZs.

## 2. The U.S. should improve the emergency exercise process for commercial nuclear power plants to make exercises more realistic and address a broader range of scenarios.

Emergency exercises need to challenge participants with both expected and unexpected scenarios, including ones that may involve protracted releases and longer-term response. Currently, due to regulatory consequences, domestic commercial nuclear power plants are unable to exercise to failure. No-fault tabletop exercises should become part of the exercise process. Other good options to increase preparedness include regional exercises (eg, Liberty RadEx) that can accommodate a number of agencies and states on a periodic basis.

## 3. U.S. federal policy should downplay use of KI and emphasize evacuation.

A major concern is that KI instills a false sense of security among the population and that demand for KI might delay evacuation. For states that have already committed to KI distribution, it would be extremely difficult to move away from that position without a substantial investment in public education. Given the likelihood that plans to provide (or predistribute KI) in the event of a nuclear accident will continue, it is paramount that the most important emergency response message is always: "Evacuate first—do not waste precious time looking for KI or waiting for it."

### 4. The U.S. government should expand preevent education and improve postevent communication.

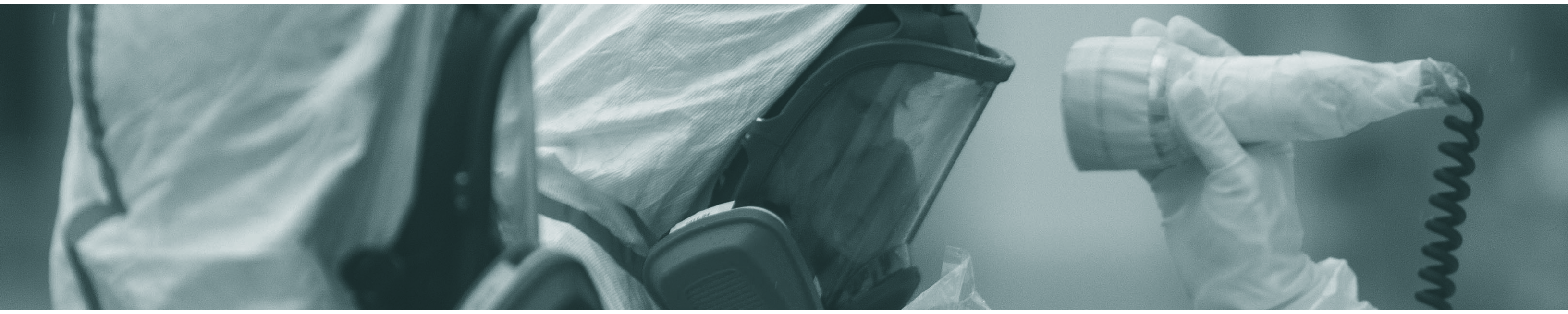
Community resilience to radiological threats in the U.S. would benefit from preevent education and postevent communication efforts that provide straightforward and actionable protective advice to the public. Public communication efforts must use all available media outlets and remain consistent across all levels of government—federal, state, and local. Ongoing federal agency efforts to understand how to educate the public before and during a crisis are important and should be supported. Furthermore, a nuclear power plant accident and a subsequent radiological release is both a technological and public health disaster. Given public concerns about the health effects of ionizing radiation, it seems important to include a health expert in the federal messaging approach alongside a nuclear regulatory official. In the future, it would be wise for the NRC and the CDC to consider jointly addressing the public about the threats posed by a compromised nuclear power plant and its public health consequences.

### 5. The U.S. should articulate a clear plan for recovery after a large-scale accident.

With a late-phase protective action guide pending for the past 20 years, and little planning and exercising being conducted for the recovery phase, a serious gap exists in U.S. recovery planning following a nuclear power plant accident. The consequence of continued inaction could be misdirection, delays, and confusion, as has been demonstrated in Japan, where the public struggles to recover lives and livelihoods. The U.S. government should publish a late-phase PAG to guide recovery planning and response, articulate its approach for recovering from a major radiological release, and develop guidance to aid state and local authorities in dealing with their responsibilities for mitigating exposure, managing decontamination and cleanup, and resettling displaced populations. This emerging set of benchmarks needs to be exercised periodically in a manner that does not detract from current emergency preparedness obligations at nuclear power plants.

### 6. The U.S. should take steps to sustain professional radiological expertise in the public sector.

A number of actions can be taken to ensure a sustained supply of this essential expertise for federal and local governments. First, the federal government once offered graduate school grants and traineeships to encourage entry by nuclear safety and health physics graduates into the public sector—that can be reinstated with relative ease and with little budgetary burden. Second, existing resources can be leveraged better to provide support where needed and, in a major emergency, shared across agencies and between geographical areas. Finally, a means to convey the experience possessed by the existing cadre of radiological response professionals should be created through a mentoring program or other participatory means by which their knowledge can be captured for their successors.



# After Fukushima:
# Managing the Consequences of a Radiological Release

> *Our nuclear power plants have undergone exhaustive study, and have been declared safe for any number of extreme contingencies. But when we see a crisis like the one in Japan, we have a responsibility to learn from this event, and to draw from those lessons to ensure the safety and security of our people.*
>
> President Barack Obama, The White House, March 17, 2011

Even amidst the devastation following the earthquake and tsunami in Japan that killed more than 20,000 people, it was the accident at the Fukushima Daiichi nuclear power plant that led the country's Prime Minister, Naoto Kan, to fear for "the very existence of the Japanese nation."

While such low-probability, high-consequence releases have been rare throughout the operating histories of existing nuclear power plants, the growing number of plants worldwide increases the likelihood that such releases will occur again in the future. Nuclear power is an important source of energy in the U.S. and will be for the foreseeable future. Accidents far smaller in scale than the one in Fukushima could have major societal consequences.

The goal of the Center for Biosecurity's After Fukushima project is to assess U.S. policies and plans for consequence management to reduce public exposure to radiation following a nuclear power plant accident and offer recommendations for strengthening those efforts. Given the extensive, ongoing Nuclear Regulatory Commission (NRC) and industry assessment of nuclear power plant (NPP) safety and preparedness issues, the Center's assessment was focused on offsite policies and plans intended to reduce radiation exposure to the public in the aftermath of an accident. The project sought to foster communication among the many federal, state, and local agencies involved in nuclear accident preparedness and response as well as relevant groups in academia, industry, and nongovernmental organizations. This report provides an assessment of Japan's efforts at nuclear consequence management; identifies concerns with current U.S. policies and practices for "outside the fence" management of such an event in the U.S.; and makes recommendations for steps that can be taken to strengthen U.S. government, industry, and community response to large-scale accidents at nuclear power plants.

# Methods

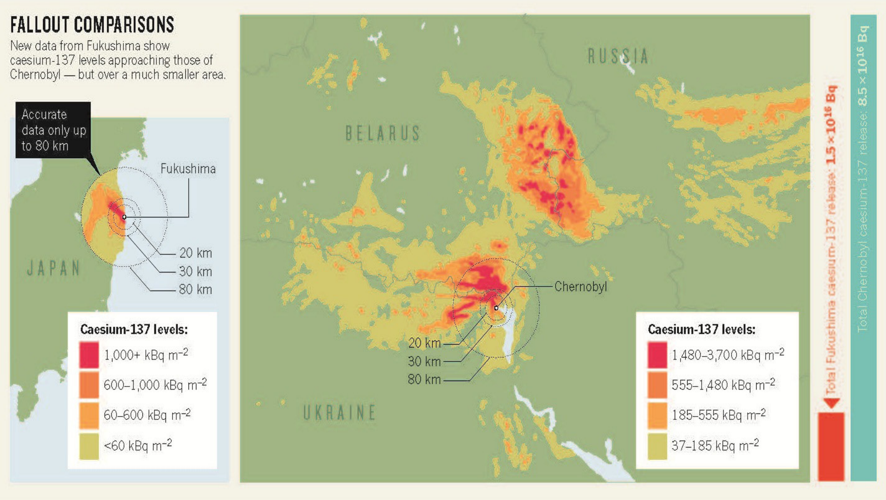
The Center studied the events surrounding the response to the Fukushima Daiichi nuclear power plant accident, reviewed current U.S. government policies and practices for nuclear consequence management, and performed a comprehensive review of the published literature and key U.S. government documents. The Center conducted a series of discussions with 94 domestic and international experts in the fields of health physics and radiological emergency management from the White House, the U.S. Centers for Disease Control and Prevention (CDC), the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), the U.S. Federal Emergency Management Agency (FEMA), the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of State (DOS), the U.S. Department of Defense (DOD), state health departments, and experts from industry, professional organizations, academia, and relevant international organizations (see Appendix A). The analysis of these conversations provided the structure for a workshop on December 13, 2012, which was attended by 26 participants (see Appendix B).

This final report presents a synthesis of the Center's scientific and policy review, a synopsis of the workshop discussion, and recommendations from the Center for Biosecurity. Both the workshop discussion and our premeeting phone conversations were held on a not-for-attribution basis. Quotes from the project participants appear in italics throughout this report but are not attributed to specific individuals. Expert input at the workshop and in the preceding interviews was considered advisory to the analysis. The Center did not attempt to achieve consensus in its discussion with experts. Accordingly, the findings and the recommendations in this report represent the analysis and judgments of the Center for Biosecurity staff and do not necessarily reflect the views of those who were interviewed for this project. The project was funded by the Center for Biosecurity.

# Background on the Fukushima Daiichi Accident

In the afternoon of March 11, 2011, a 9.0 magnitude earthquake occurred off the Pacific Coast of Japan, causing 15-meter tsunami waves that overwhelmed the protective seawalls of the Tohoku region. The earthquake and subsequent tsunami alone constitute one of the worst natural disasters in Japan's history, with more than 20,000 victims and a projected cost of over $300 billion.[1] At the time of the earthquake, 6 nuclear power units stood at the Fukushima Daiichi NPP. The earthquake triggered a scramming process through which the 3 reactors in operation initiated an emergency shutdown process, and external power to the reactors was lost. The subsequent tsunami and breach of the protective seawall flooded the back-up power units at the Fukushima Daiichi NPP, causing the reactors and spent fuel pools to lose their cooling capabilities. On March 12, explosions occurred at 3 units, which are assumed to have been caused by pressure from the hydrogen released by damaged reactor cores, leading to a large release of radioactive materials.[2] By the end of the day on March 12, the Japanese government had extended mandatory evacuation from a 10-km to a 20-km radius from the Fukushima Daiichi NPP. In total more than 110,000 people have been evacuated.[2] Due in part to the heavy containment vessels at Fukushima, the total radioactive release from the Fukushima Daiichi NPP is currently estimated at about 5.5% of that of the Chernobyl accident. The prevailing winds at the time of the accident appear to have blown a significant portion of the radioisotopes out to sea. Nevertheless, in terms of Cesium-137 (Cs-137) contamination, a radioisotope with a half-life of 30 years, the Fukushima plant has released about one-fifth of the amount of Cs-137 that was released during the Chernobyl accident over a significantly smaller area of land (Figure 1).[3] The extensive cesium contamination in the areas around Fukushima Daiichi NPP and neighboring prefectures (with deposition projections well over 100,000 MBq $\text{km}^{-2}$) represent an unprecedented challenge in decontamination and recovery efforts.[4]

Figure 1. Comparison of Cs-137 Contamination Between Fukushima and Chernobyl



**Source:** Brumfiel G. Directly comparing Fukushima to Chernobyl. Nature News Blog. 2011. http://blogs.nature.com/news/2011/09/directly_comparing_fukushima_t.html. Accessed February 8, 2012. Reprinted with permission.

In the United States, the EPA and the DOE jointly announced on March 18 that their network of domestic radiation-monitoring stations, known as RadNet, had detected miniscule levels of radioactive iodine presumed to be from the Fukushima Daiichi NPP accident. However, all of the levels detected through RadNet were well below levels that constitute a public health concern; thus, no protective actions were determined to be necessary.[5]

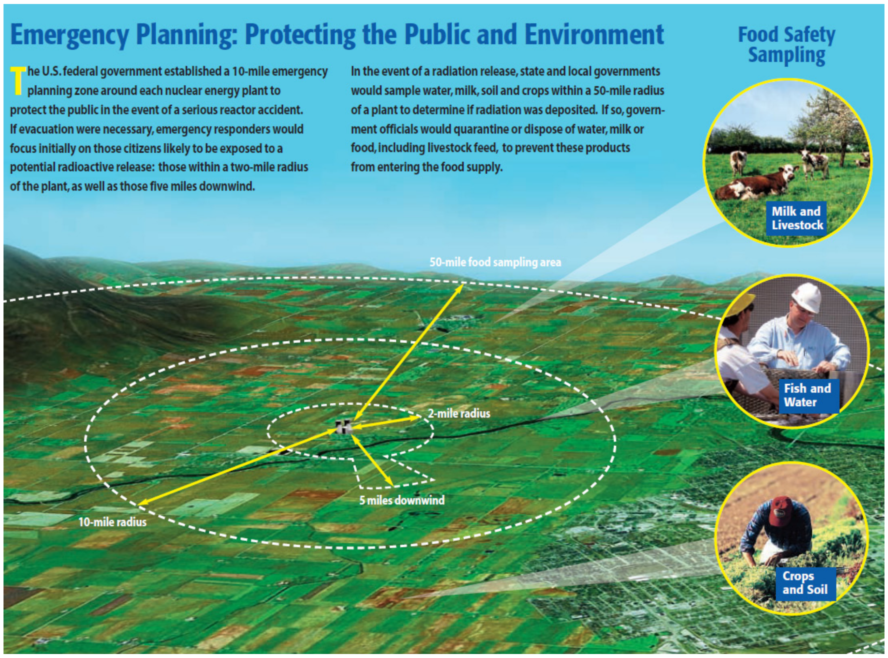
# Outside the Fence Issues:
# Increasing Resilience and Protecting the Public

The NRC is now assessing nuclear safety and preparedness issues, or "inside the fence" issues, to ensure the integrity of U.S. commercial NPPs. While efforts to prevent an NPP accident should remain a top priority, the Center's analysis of lessons learned from the Fukushima Daiichi accident focused on offsite policies and plans, or "outside the fence" issues, intended to reduce radiation exposure to the public following a radiological release from a commercial NPP.

## Issue 1: Emergency Planning Zones and Protective Action and Guidelines

For Americans living within 10 miles of a nuclear reactor, the conspicuous tests of public alerting systems, community-wide public education programs, and possibly the distribution of potassium iodide (KI) serve as regular reminders that their community is located in an emergency planning zone (EPZ). According to FEMA, EPZs are meant to establish "areas for which planning is needed to assure that prompt and effective actions can be taken to protect the public in the event of an accident."[6] Each nuclear reactor is surrounded by 2 circular planning zones: the Plume Exposure Pathway EPZ, covering a 10-mile radius around the reactor, and the Ingestion Exposure Pathway EPZ, which encompasses a 50-mile radius surrounding each reactor (Figure 2).[6] Within these areas, state and local governments take predetermined specific preparedness precautions. Within the 10-mile EPZ, state officials and NPP operators work with locals to distribute educational materials and potassium iodide (KI) and plan evacuation routes and test emergency alert systems. Within the 50-mile EPZ, state agencies (emergency management, public health, agriculture) develop actions to protect the food supply and to prevent the ingestion of potentially contaminated foodstuffs.

Figure 2. U.S. Emergency Planning Zones for a Nuclear Power Plant



Emergency Planning: Protecting the Public and Environment

The U.S. federal government established a 10-mile emergency planning zone around each nuclear energy plant to protect the public in the event of a serious reactor accident. If evacuation were necessary, emergency responders would focus initially on those citizens likely to be exposed to a potential radioactive release: those within a two-mile radius of the plant, as well as those five miles downwind.

In the event of a radiation release, state and local governments would sample water, milk, soil and crops within a 50-mile radius of a plant to determine if radiation was deposited. If so, government officials would quarantine or dispose of water, milk or food, including livestock feed, to prevent these products from entering the food supply.

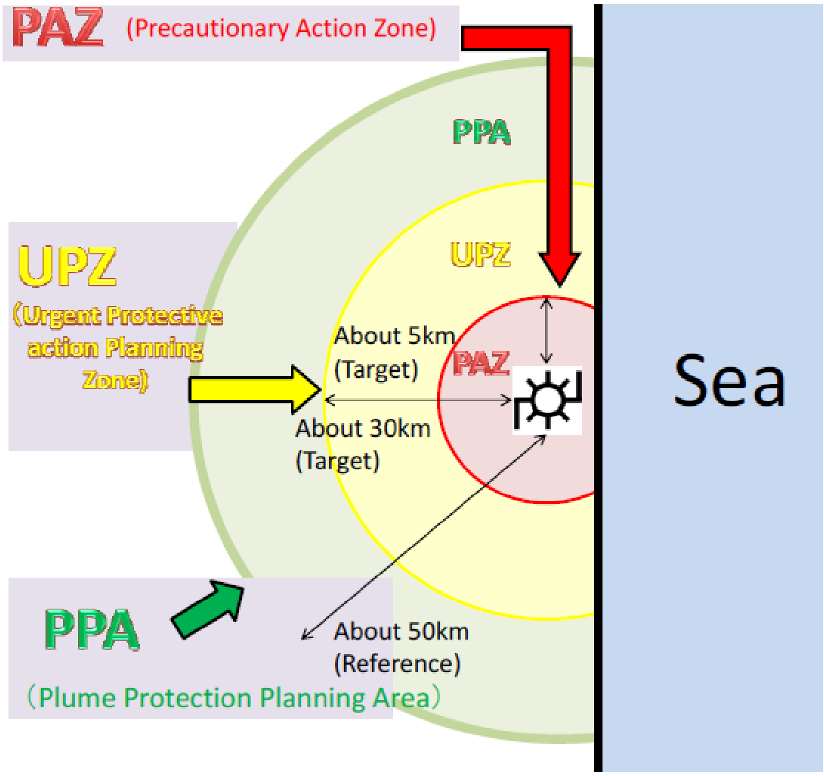
Source: Nuclear Energy Institute. Emergency Planning: Protecting the Public and Environment. http://resources.nei.org/documents/japan/EP_Protecting_the_Public_and_Environment.pdf. Accessed February 14, 2012. Emergency Planning in Japan. Reprinted with permission.

Prior to the Fukushima Daiichi accident, Japan also used an EPZ system for emergency planning around its nuclear power plants. During the Fukushima Daiichi NPP accident, the Japanese government decided to expand its standard evacuation zones as it became clear that radioisotope contamination exceeded initial estimates. Because most of the meteorological and radiation detection system was disabled by the earthquake and tsunami, the Japanese government relied heavily on the EPZ concentric circle models in issuing evacuation orders instead of the more sensitive model for projected plume path based on real-time weather conditions and radiation monitoring, known as the System for Prediction of Environment Emergency Dose Information (SPEEDI), which would normally be relied upon in emergency response efforts. On March 11, people within a 1.9-mile (3-km) radius range from the Fukushima Daiichi NPP were ordered to evacuate. By the afternoon of March 12, the Japanese government had instituted evacuation orders that extended to a 6.2-mile (10-km) radius. By nightfall on March 12, the evacuation orders were issued for residents within a 12.4-mile (20-km) radius of the NPP.[7] Then, 4 days after the tsunami, on March 15, residents within the 20- to 30-km radius range were instructed to shelter in place.[8] Without immediately available environmental monitoring, Japanese officials based evacuation decisions on ongoing assessments of the condition of the stricken NPP, estimates of the amount of radioactive material released, and meteorological forecasts provided by the World Meteorological Organization (WMO). As conditions continued to deteriorate and a second hydrogen explosion occurred in Unit 3 of the NPP on March 14, Japanese officials were forced to reactively evacuate areas further from the plant. The expanding evacuation zones and ostensibly rapidly deteriorating conditions at the plant prompted response beyond Japan. Fearing further releases, U.S. NRC Chairman Gregory Jaczko advised Americans living in Japan to evacuate areas within 50 miles of the plant.[9]

At the time of the Fukushima accident, Japanese planning policies required a single emergency planning zone with a radius of 4.97 to 6.21 miles (8-10 km) around nuclear reactors, encompassing approximately 121 square miles. The Japanese government took protective actions in a larger area than the Fukushima reactor's EPZ, including the evacuation of residents living up to 12.42 miles (20 km) from the reactor, and directing residents living from 12.42 to 18.64 miles (20-30 km) to shelter in place. These protective actions applied to an area amounting to 1,091 square miles—more than 9 times larger than the standard 8- to 10-km EPZ.[10]

In light of the Fukushima Daiichi experience, a special working group within the Nuclear Safety Commission (NSC) of Japan has proposed altering the EPZs around Japan's 17 nuclear power plants (Figure 3).[11]In an effort to improve the timeliness of decision making during a radiological release, the NSC recommends replacing the existing EPZ with a 3-tiered emergency planning strategy. The 5-km (3.1-mile) radius surrounding an NPP would constitute the precautionary action zone (PAZ), within which unconditional protective actions are instituted (eg, evacuation) once a plant reaches an Emergency Action Level (EAL). An EAL is a predetermined, site-specific observable disruption in NPP function that would constitute an emergency prior to any release of radioactive materials. The second tier would be a 30-km (18.6-mile) Urgent Protective Action Planning Zone (UPZ) in which protective actions would be dependent on environmental monitoring for radiation within the 30-km circle around the NPP. The third tier would apply to residents in the 31- to 50-km (19.3-31.1-mile) zone, which would constitute the Plume Protection Area (PPA) in which practical protective actions would be recommended to prevent exposure as the radioactive plume passes (eg, sheltering indoors).[11-13]

Figure 3. Proposed Restructuring of the Emergency Preparedness Zones Surrounding Nuclear Power Plants in Japan



Nuclear Safety Commission of Japan. Concept of areas in which arrangements for emergency preparedness and response for nuclear power plants should be intensively made. 2011. http://www.nsc.go.jp/NSCenglish/geje/20111101review_1.pdf. Accessed February 8, 2012. Reprinted with permission.

The motivation of the Japanese NSC for altering the EPZ framework is 2-fold. First, plume contamination from the Fukushima NPP exceeded the existing 8- to 10-km EPZ for anticipated evacuation due to plume contamination.[12] Second, uncertainty regarding the condition of the NPP compounded by the failure of the SPEEDI caused delays in evacuation orders. The delays and confusion endangered local residents and exacerbated domestic and international panic. Part of Japan's motivation for altering its EPZ framework is that "areas within a 20-km radius of the Fukushima No. 1 plant—far wider than initially expected—became off-limits after the accident."[13] By including a new 5-km unconditional protective action planning zone where evacuation would be mandatory when an EAL is broached, Japan hopes to avoid repeating unnecessary time lags in the decision-making process that occurred during the Fukushima accident. The operability of the Japanese monitoring systems raises additional questions about preevent planning. Given that the tsunami appears to have compromised the network of monitors in Japan specifically, and that an accident of this scale is likely to jeopardize existing infrastructures in general, emergency responders should be prepared with radiation monitoring systems that do not depend on these infrastructures (eg, landline electrical supply).

## Implications for U.S. Emergency Planning Zones

The notion that protective actions may be required beyond the strict numerical boundaries of an EPZ predated the accident in Fukushima and has factored into U.S. planning. The NRC's original guidance establishing the EPZs noted that, should response efforts be necessary beyond the planning zones, the detailed preevent planning done within the EPZ is meant to "provide a substantial base for expansion of response efforts" to areas outside the EPZ.[6] The emergency response surrounding the Fukushima Daiichi NPP validates this anticipatory approach to expanding emergency response efforts as an accident unfolds. But the accident also raises questions about the trade-off between making decisions in real-time and the advantages of emergency response decisions that are automatically triggered in the event of an impending radiological release. It would be worthwhile for the U.S. to reevaluate its own evacuation protocols to include mandatory evacuation zones, which could prevent delays in evacuation and radiological exposure, given the Japanese experience. Furthermore, the breadth of contamination found in Japan, which extended beyond 30 km (18.6 miles), suggests that a 10-mile plume exposure EPZ may be inadequate. The NRC has recognized in its near-term review of the Fukushima Daiichi accident that "while the U.S. EP framework has always noted that the plume exposure pathway EPZ provides a basis for expansion, insights from real-world implementation at Fukushima, including the realities of multiunit events, might further enhance U.S. preparedness for such an event."[14] The NRC and FEMA should evaluate the sufficiency of the EPZ structure surrounding U.S. commercial NPPs based on the Fukushima Daiichi experience.

## State and Local Readiness

A 2010 report by the Council of State and Territorial Epidemiologists (CSTE) found that the public health system remains poorly prepared to adequately respond to a major radiation emergency incident.[15] This finding was echoed by state and local representatives in this study who felt that, as compared to infectious public health threats like pandemic influenza, state and local capacity to respond to radiological hazards is lacking. According to project participants, one reason is a comparative lack of expertise in the public health community in emergency radiological event response, starting with CDC's capacities down to the public health infrastructure at the county and local levels. The later stages of a radiological emergency would rely heavily on public health expertise and response, but most of the country's capabilities, resources, and experience reside with the agencies traditionally associated with nuclear energy and environmental safety: NRC, DOE, and EPA. In some cases, state and local public health authorities have developed capabilities to respond to conventional radiological events (such as accidental exposures from medical devices) but are concerned about their capacities to scale up to large-scale contamination events such as Fukushima.

**Protective Action Guidelines (PAGs):** Protective Action Guidelines were developed by the U.S. EPA to help state and local authorities make radiation protection decisions. The PAG manual currently provides advice for the early and intermediate phases of an accident based on levels of anticipated radiation exposure.[16] For example, during the early phase of a radiological event, the EPA recommends evacuating an area if the expected dose for the first few days of the accident exceeds 1 rem[*]. During the intermediate phase of an event, the EPA recommends relocation of populations from an affected area if the *annual* projected dose is expected to exceed 2 rem.[16] Of note, DHS provides distinct PAG threshold limits for emergency response professionals during the early phases of an accident.[17]

The U.S. PAG manual differs from protective guides used by the international community, known as Operational Intervention Level (OIL), which are defined as the values of environmental measures of radiation, like radiation dose measurements, above which specific actions should be taken in emergency situations.[18] OILs differ from PAGs in that they do not depend on projected dose calculations. Instead, they recommend

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[*] Rem stands for "roentgen equivalent man" and is a unit of radiation dose equivalent used to measure the effects of ionizing radiation on humans.

actions based on real-time measurements, often using on-the-ground field measurements, possibly allowing for a faster response. For example, one could perform multiple ground-level radiation measurements throughout an area thought to be contaminated. Then, based on the radiation level and time since the accident, the OILs recommend a suitable protective action. Because OILs use real-time field measurements and do not rely on pre-placed radiation monitoring stations, this system is less vulnerable to the types of disasters that threaten the safety of a nuclear power plant. In fact, pre-placed radiation monitoring stations around the Fukushima NPP were unusable after the disaster. The U.S. should reevaluate the relative balance of PAGs and OILs used in response planning to an NPP radiological release given the disruptions to the radiation monitoring systems witnessed in Japan.

> *"Traditional exercises have become perfunctory."*

**Exercises:** U.S. nuclear power plants are required to exercise emergency plans with the NRC, FEMA, and offsite authorities at least once every 2 years to ensure state and local officials remain proficient.[6] FEMA's role is to review and provide findings to the NRC on planning and preparedness activities of state, tribal, and local governments; licensee emergency response organizations, if applicable; and other supporting organizations.[19] The NRC, on the other hand, is responsible for overseeing the overall status of emergency preparedness.

Some project participants conveyed that current exercise activities may not be done rigorously or frequently enough to adequately prepare nuclear power plant areas for a major event. Exercises are divided into 2 categories: plume phase and ingestion phase. The plume phase exercises focus on practicing the measures that would need to be taken in the immediate vicinity of a nuclear power plant to protect residents from inhalation exposure. The ingestion exercises focus on practicing measures that would need to be taken over larger areas to prevent the ingestion of radiological fallout after the plume had settled. Project participants noted that, for funding reasons, the ingestion pathway exercises may be moved from being performed every 6 years to every 8 years. Participants cautioned that this could jeopardize the institutional experience of a public health department, as staff turnover is highly likely over an 8-year cycle. Participants also noted that few exercises are performed as "no notice," and exercises do not test to failure for fear that a plant may be forced to shut down. In order to enhance the rigor and utility of the exercises, participants suggested "no fault" exercises that would permit plants to continue operating following an exercise that had tested to failure while necessary adjustments are made.

The issue with which all parties grapple is the conundrum of how to prepare meaningfully for radiological accidents like the one at Fukushima that may occur only once in a generation. There is a policy divide between those who believe preparedness requires attention to low-probability, high-consequence events, such as that represented by the Fukushima accident and akin to preparing for the 100-year flood or hurricane, versus those who believe preparing for such low-probability events would siphon scarce resources away from more probable immediate needs. The Center's judgment is that serious planning for low-probability, high-consequence events is critically important, especially if done in a resource-efficient way.

> *"Preparing for a Fukushima-type event in the U.S. is like putting a spare tire in the trunk of your car. Are we willing to take the time and spend the money to prepare for something that may never happen in our lifetime?"*

**Human Capital in Radiation Safety:** As the 2010 CSTE report points out, few full-time employees work in radiation emergency response in state public health departments.[15] The Center's investigation also found that in the post–Cold War era, there are fewer incentives academically and professionally to pursue careers in health physics, thereby exacerbating the lack of expertise in public health departments. According to the Health Physics Society, the number of students graduating with BS, MS, or PhD degrees in health physics declined steadily in recent years.[20]

Project participants suggested that the U.S. government should incentivize careers in health physics by providing traineeships or graduate school grants contingent upon public service in the field following graduation. Some in industry have formed relationships with local educational institutions, providing scholarships and training to ensure a pipeline of qualified graduates. In the meantime, efforts are under way by the Conference of Radiation Control Program Directors (CRCPD) to incorporate local volunteer radiation professionals into existing health volunteer programs to assist in the response to a radiological event.[21] As another way to augment the trained workforce in the aftermath of an accident, it was suggested that the CDC might engage health physicists from around the country to be available to help with response. A network of trained professionals could help with radiation screening and assessment, much as the Medical Reserve Corps provides medical assistance during catastrophic health emergencies by, for example, administering vaccinations during pandemic flu.

> *"The health physicist/radiation expert community is very small and shrinking."*

## Issue 2: Potassium Iodide (KI) Policy

One of the byproducts of the nuclear fission of plutonium or uranium in a nuclear plant's reactor core is the beta- and gamma-emitting isotope radioactive iodine or radioiodine (I-131). This radioactive isotope has a half-life of 8 days and poses a human health threat in the form of thyroid disease.

The thyroid gland is the major target of I-131 because, unlike other tissues, it is able to store I-131. At high doses, I-131 causes thyroid cell death leading to hypothyroidism, but at lower doses DNA damage occurs, leading to mutations and possibly malignancy.[22]

### Exposure Pathways: Ingestion and Inhalation

After a release of I-131, the principal means of human exposure is through inhalation and/or ingestion of contaminated milk, vegetables, and water. The inhalational pathway of exposure is most prominent in the 10-mile radius surrounding a nuclear power plant, while ingestion can occur over a wider area (50 miles). However, after the Chernobyl accident, the inhalation exposure route was not the primary route of radioiodine exposure. Consumption of food and water that had been contaminated with radioiodine prior to its dissipation was the chief means of exposure.[23] For this reason, project participants emphasized that Chernobyl data cannot be extrapolated to the U.S., as FDA, EPA, and USDA interdiction would eliminate the ingestion pathway.

### I-131 and Thyroid Cancer

The thyroid gland displays an age-related sensitivity to the effects of I-131. Because younger individuals have faster growing thyroid glands, consume more milk, and breathe faster (allowing more inhalation of I-131), a child's thyroid gland is exquisitely—and almost exclusively—at risk for the deleterious effects of 1-131. Because the fetal thyroid gland can concentrate I-131 at 3 months' gestation, it is also susceptible to I-131's effects. The carcinogenic effects of I-131 are also accentuated by iodine deficiency, which was prevalent in the populations exposed during Chernobyl. The Hanford Study, which assessed the risk of thyroid disease in U.S. populations exposed to I-131 from a nuclear weapons facility, found no increased risk for thyroid cancer in any age group—a finding that one project participant stated was likely due to the iodine-replete status of the U.S. population. Based on the available science, including the data from Chernobyl as well as Hiroshima, the National Academies of Science has concluded that "the risk of thyroid carcinoma in adults exposed to radioactive iodine in fallout is very low, and can be assumed to be absent for adults over 40 years old although at very high doses there is a risk of hypothyroidism."[22]

## KI Blocks Absorption of I-131 by the Thyroid Gland

KI is an FDA-approved pharmaceutical product used to block the uptake by the thyroid gland of I-131 after an environmental release. It was approved by the FDA in December 1978. The use of KI decreases the risk of the development of a subsequent thyroid cancer by saturating the thyroid gland with iodine and rendering it unable to absorb carcinogenic I-131. KI is available over the counter, and, currently, 3 formulations are commercially available in the U.S. For KI to be most effective, it has to be ingested a few hours prior to exposure, with diminishing protection as the time to exposure decreases or if KI is administered postexposure.

The FDA guidance specifies that KI be taken when the predicted thyroid exposure is 50 milli Seiverts (mSv) for children, pregnant women, and breast-feeding women; 100 mSv for adults between 18 and 40 years; and >5 Sv for those above age 40.[24]

Several adverse events can occur with KI administration, including gastrointestinal symptoms, allergic reactions that could be life threatening, and transient changes in thyroid function. Project participants stressed that while the individual level risk for the occurrence of these side effects is low, as larger populations are administered KI, the absolute numbers of those experiencing side effects could become large.

> *"Even though the probability of deleterious effects of KI are low, you're giving it to more people, so the absolute number of cases will increase."*
>
> *"The over dosage of potassium iodide is a real issue. I saw kids back in Ukraine with these tremendous inflammatory salivary glands from the iodide overdosing. Mothers thought the more you give the better the kid is."*

## NRC, FEMA, and State Policies on KI

Prior to 2001, no federal government guidance on KI existed. In January 2001, the NRC implemented a program to distribute KI to states located within the 10-mile EPZ of a nuclear power plant. At that time, both the NRC and FEMA declared that KI should be *considered* for the general population within the 10-mile EPZ as a supplement to evacuation.[25] Prior to this program, only 3 states had developed KI plans. Currently, 24 (of 33 states) states within the 10-mile EPZ employ KI in their emergency planning, while 9 do not. In spite of the FDA guidance, project participants whose states employ KI stated that a blanket order to take KI for all populations would be issued once the lowest threshold was reached because of the difficulties of nuanced communication during an emergency.

> *"We would issue a blanket order to take KI, irrespective of age and exposure."*

The Public Health Security and Bioterrorism Preparedness Act of 2002 contained a provision to expand the distribution of KI to a 20-mile radius from the existing 10-mile radius. However, the provision could be waived if an alternative and more effective prophylactic measure existed. In 2007, the President's science advisor, John Marburger, waived the provision in response to a FEMA study that concluded that evacuation is more effective than KI for those residing in the 10- to 20-mile range.[26]

> *"There is no plausible scenario where KI would have to be disbursed; there are no CONOPS."*

KI is stockpiled in the strategic national stockpile (SNS). However, there are few plausible scenarios in which KI distribution from the stockpile could occur quickly enough to make a major difference in a community. During Fukushima, Japan made a preliminary request for KI from the U.S. stockpile, but it was eventually not needed. Little KI was administered to the Japanese population as radiation thresholds for KI administration were not exceeded.

> *"Fear is a health and medical issue. There's a non-zero need for KI. So if you have no countermeasure you can't say the countermeasure isn't needed and have credibility. You have to have some available, so you can say you don't need it."*

The Center's judgment is that U.S. KI policy should be reevaluated. KI is solely effective against I-131 in a specific segment of the population and only if administered in a delimited time period. For the majority of people, KI is of no value. In order to be most effective and minimally affect evacuation, KI must be predistributed, but in one study less than 20% of residents who had received KI in a predistribution program could locate their KI.

> *"KI is a good example where science, emotion and misinformation collide with each other. We did a terrible job managing the epidemic of fear."*

## Issue 3: Communications and Public Health Education

Public communication challenges are present during both the acute phase and recovery phases of nuclear reactor emergencies. During the acute phase, when inhalation of radioactive materials and high-level exposure risks are greatest, the public relies on local and federal officials to provide immediately actionable, protective advice. During the recovery phases, when exposure to low levels of ionizing radiation becomes the paramount public health issue, government communications must provide reassurance and rationale for policies of acceptable risk in contaminated areas. In all cases, rapid and responsive communication from government officials is essential to maintaining the public's trust. Conversely, withholding information, even if it is incomplete, from the public can be disastrous in nuclear disaster management. The Fukushima Daiichi accident highlighted the global communication challenges associated with a radioactive plume release.

### Communication During the Acute Phase of the Fukushima Accident

During the first day following the tsunami and the deteriorating conditions at the Fukushima Daiichi plant, thousands of residents in the town of Namie evacuated north to Tsushima to avoid the radioactive plume. In the absence of publicly available forecasts and radioactive plume predictions from the government in Tokyo, town officials in Namie advised residents to evacuate to Tsushima based on seasonal expectations that the winter winds would be blowing south. Town officials would learn 2 months later that the winds had actually been blowing directly toward Tsushima, making it one of the areas of highest radioactive contamination.

> *"An uninformed public cannot make good decisions. If we are educating when the public is not under stress, they'll be more likely to respond appropriately during an event."*

A *New York Times* investigation in August 2011 revealed that federal officials in Tokyo may have attempted to avoid public panic and criticism and costly large-scale evacuations by leaving the forecasts and projected plume path unpublicized.[27] Japanese government officials pointed out that the delay in the release of plume data was due in part to suboptimal performance of Japan's radiation monitoring system, SPEEDI. The tsunami had knocked out many of the radiation monitors used by SPEEDI, creating an incomplete portrait of the plume's trajectory. Nevertheless, the perception that the government had knowingly withheld even incomplete information that may have allowed evacuees like those from Namie to make better decisions led to lawsuits against the federal government and broader mistrust of government officials as the country moved into the recovery phase.

> *"We need a simple sound bite like 'drop and cover.' We need to get that out so the public knows how to react appropriately."*

Federal officials in the U.S. struggled to communicate the exceedingly low level of threat to U.S. residents as the plume traveled east over the Pacific. Based on the Center's interviews with federal, state, and local officials, there seemed to be a sense that U.S. communications efforts were hampered by an impulse to avoid frightening the public by focusing too much on radiation. Even though many government officials fully anticipated that low levels of radiological contamination would reach the West coast, federal communications efforts to preempt possible public health concerns were not pursued. Instead, public health officials at the state and local levels were surprised by a surge in public anxiety and a demand for potassium iodide (KI) when the presence of radionuclides in the U.S. was announced in the media.

> *"The more people have to wait to get information—the more they have to ask for information—the more the perception is something's being hidden."*

## Communication During the Recovery Phase of the Accident

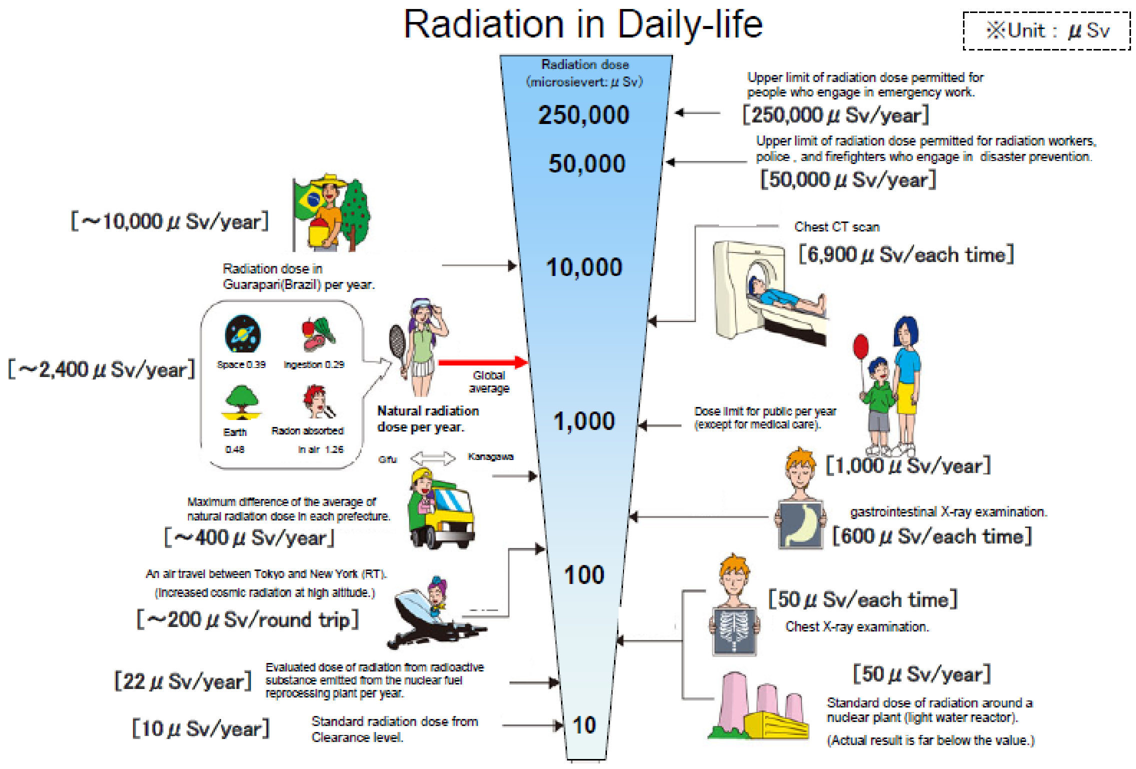
As the focus of the Fukushima Daiichi accident shifted from the integrity of the nuclear reactor plant and the immediate repercussions of more radiological releases, many of the challenges of communicating to the public about the risk of environmental radiation contamination came to the forefront of crisis management. Efforts to set acceptable levels of radiation that would facilitate recovery in Japan were complicated by public fears and lack of knowledge about radiation. From a risk perception standpoint, nuclear reactor accidents rank among the highest in technologies that are uncontrollable, catastrophic, and lethal.[28] Ionizing radiation from nuclear disasters evokes an unparalleled sense of dread compared to other potential health threats, like carbon dioxide, mercury, and pesticides, or even other sources of radiation such as X-rays in the medical setting or radon in the household setting. Although there were no casualties from the accident at Three Mile Island (TMI), TMI seems to have augmented the American perception that nuclear accidents are disasters of "immense proportions."[28]

*"Ionizing radiation is, from a public risk perception standpoint, the proverbial boogeyman."*

The fear of ionizing radiation combined with low baseline public knowledge about radiation created a tremendous communication and education challenge in Japan. According to one project participant, the Japanese government began distributing textbooks and other educational materials on radiation throughout the Fukushima prefecture. It also became clear that levels of radiation as measured by traditional metric units (eg, Sieverts) are meaningless to the public. Relative risk diagrams comparing the levels measured in and around Fukushima to what one might receive on a long plane ride or in a CT scan attempted to provide the public with some relatable form of information that could serve as a rationale for the public exposure limits determined by the Japanese government (Figure 4). Participants suggested that while these charts may prove helpful in translating radiation measurements to health concepts, there is overriding demand by the public to receive actionable advice that will help them protect themselves and their dependents.

> *"Forget the educational messages that we prepared. The public wants to know if it is safe for themselves and for their kids. And, if not, what do they do about it, period. They don't care what a Sievert is."*

Figure 4. Comparative Levels of Radiation Exposures from Daily Life



(Ref) Average dose rate at the monitoring post of Tokyo (3/17 9:00~3/18 9:00, March) : 0.050 μ Sv/h = 438 μ Sv/y

Ministry of Education, Culture, Sports, Science, and Technology – Japan (MEXT). Radiation in Daily life. http://radioactivity.mext.go.jp/en/related_information/radiation_in_daily-life/. Accessed February 9, 2012.

## Communication in the Information Era

In contrast to the accidents at Three Mile Island and Chernobyl, the Fukushima Daiichi accident occurred during an era of 24/7 news cycles, social media, and the internet. Efforts to inform the public were complicated by the influx of conflicting voices from a variety of media outlets. On a cable news channel in the U.S., William Nye, known popularly as Bill Nye the Science Guy, misspoke by confusing cesium with boron as the element used to "slow and control the nuclear reaction" in the nuclear reactor vessel. Nye potentially heightened public fears by suggesting that cesium's presence in the plume indicated a core meltdown situation that was "more serious than people have announced." On a local news broadcast in California, amid fears that the plume from Fukushima would pose a public health risk for the West coast, the U.S. Surgeon General added to the public fear by remarking that it was "definitely appropriate" for residents to purchase KI pills even though such pills would provide no health benefit to those living in California. In Asia, an SMS text purporting to be from the BBC caused panic and propagated misinformation by suggesting that the public needed to take "necessary precautions," such as swabbing "neck skin with betadine" to protect the thyroid. The sheer volume of information available to the public at large was demonstrated by a Google search of "Fukushima and radiation" that returned 22.4 million results just 4 months after the accident. On one hand, the rapid and dynamic nature of the internet enhanced the ability of traditional media outlets, such as the *New York Times* and the *Wall Street Journal*, to provide nuanced, real-time coverage with animated graphics. However, it also facilitated the dissemination of unvetted voices and opinions.[29]

> *"Social media dominated the landscape. Even the news networks were pulling from social media and then broadcasting it as fact and as news. And if you're not in that game, then you're just not there."*

## Government Role in Communication

The value of a unified federal voice and federal spokesperson has been repeatedly demonstrated during times of crisis. The accident at TMI highlighted the value of a U.S. spokesperson during a radiation crisis to communicate with the public and interface between industry, the federal government, and local governments.[30] During the H1N1 influenza pandemic, Richard Besser (then Acting Director of the CDC) served in this role, as did Thad Allen as the national incident commander for the Deepwater Horizon oil spill. No similar central spokesperson in the U.S. emerged following the Fukushima accident. Project participants suggested that U.S. communication during the Fukushima accident would have been best shared by 2 spokespeople. Because a nuclear power plant accident and a subsequent radiological release are both technological and public health disasters, and given public concerns about the health effects of ionizing radiation, it seems important to include a health expert in the federal messaging approach alongside a nuclear regulatory official. In the future, it would be wise for the NRC and the CDC to consider jointly addressing the public about the threats posed by a compromised nuclear power plant and its public health consequences.

> *"There was a demand on the part of the media to let the public know. Because there was no public spokesperson identified, it was a free for all."*
>
> *"The H1N1 communications were deliberate, and delivered by a doctor with precautionary advice and statistics. We didn't see that during Fukushima, and it was detrimental."*

Another important feature of effective communication is a preplanned strategy to disseminate information to affected areas. An established channel of communication from the federal government in Tokyo to town officials in Namie may have averted the faulty evacuation into the plume. In the U.S., where a state governor would be responsible for mandating evacuations, the interface of the federal government with state and local officials will be especially important. A good example of a well-organized communication process is the Chemical Stockpile Emergency Preparedness Program (CSEPP), a program jointly managed by DHS and the Department of the Army that provides emergency preparedness assistance and resources to communities surrounding the Army's chemical warfare agent stockpiles. The CSEP Program reaches out to community organizations, churches, businesses, and other public entities for preevent planning to establish rosters of people that needed to be phoned or texted should an emergency occur.[31] There does not appear to be an analogous top-down process in the Radiation Emergency Preparedness Program (REPP). Proactive messaging positions the government to fill the void of information immediately following an accident and combat the flood of information that will persist from unvetted media outlets in the weeks and months following an accident.

> *"The trust in the personality of the person giving the message is almost as important as, or more important than, the message itself. And I would urge anyone to pick out that person beforehand."*

## Issue 4: Reentry and Recovery Policy

Following an NPP accident, the reentry and recovery process may represent the most challenging issue to policymakers because it must balance uncertain health risks of low levels of ionizing radiation with the economic and psychosocial costs of restricting access to contaminated areas. At its root, the challenge comes from defining acceptable radiation risk and balancing that risk with other socioeconomic priorities in determining decontamination criteria and reentry and resettlement policies. Such definitions are likely to come best from risk-based guidelines and experience, coupled with full engagement between government and citizens *before* and after a major radiological release.

Two months after the Japanese government officially ordered the evacuation of the village of Iitate, Mari Kobayashi, a 46-year-old widow, insisted on returning to her abandoned town, saying, "Some people have decided that nowhere in Fukushima is safe. . . . I respect their decision, but I'm glad I didn't escape too far. Radiation is frightening, but there is a life beyond it."[32] Indeed, should a comparable nuclear accident occur in the United States, U.S citizens would be faced with difficult decisions about when to return to their communities and how to best utilize their land after an accident. Long-term abandonment of land surrounding a malfunctioning plant is both unlikely and undesirable, especially given the distinct economic opportunities and growing communities near U.S. nuclear facilities. In the U.S., 26 of the 100 most populous cities are located within 50 miles of a nuclear plant, and the number of people living within the 10-mile EPZs around U.S. nuclear power plants rose by 17% in the past decade, compared with an overall increase of less than 10% in the U.S. population.[33]

While national leadership and support will always be critical, the history of recent U.S. disasters suggests that local and state authorities will bear the brunt of both responsibility and decision making during disaster recovery and resettlement. A familiar refrain at the state level was reflected by one radiological response manager who participated in the Center's project: "The hard part for anyone is moving from the response phase to the recovery phases. The response phase is federally focused. The states and locals lead the long-term recovery." Accordingly, state and local officials have expressed concern over the lack of recovery guidelines from the federal level that would facilitate local actions. In an era of diminished government resources, state and local authorities have taken innovative approaches to stretch both limited radiological staff resources and capabilities. One key initiative has been the establishment of the National Alliance for Radiation Readiness (NARR), a collaboration that includes the National Association of County and City Health Officials (NACCHO), the Association of State and Territorial Health Officials (ASTHO), the CDC Radiation Studies branch, the Council of State and Territorial Epidemiologists (CSTE), and the CRCPD. The NARR provides a coordinating and awareness-raising platform to share resources and best practices among radiation professionals and government agencies. The NARR website currently acts as a clearinghouse for the exchange of relevant information such as incident response guidelines and radiation fact sheets. Moving forward, organizations like NARR will be essential third parties in establishing the roles of federal, state, and local officials in a coherent recovery strategy.

> *"Recovery criteria need to be discussed in advance with all stakeholders, because trying to define such a significant policy is insanity during an emergency."*

## Federal Late-Phase Policy

Twenty years ago, the EPA published the PAGs as the official decision-making document to be used during a radiological emergency. The PAGs establish principles for early and intermediate-phase response, but the agency deferred writing its chapter on the late phase, or recovery phase, indicating that "additional radiation protection guidance for recovery will be developed at a later date."[16] Almost immediately after the publication of the PAGs in 1992, an interagency working group dedicated to developing late-phase guidance was convened.[34] In January 2009, its findings were published as a draft for public comment. The draft was, according to project participants, withdrawn for consideration by the incoming EPA Administrator later that month. In January 2011, the EPA distributed a "significantly revised version" of the late-phase PAGs to the interagency working group for review. Until that review is completed and late-phase PAGs are published, there won't be clear federal policy for recovery and reentry after a nuclear accident.

> *"In a situation where you have widespread contamination and important infrastructure, you may not be able to get to background, so you'll need a 'new normal.'"*

## How Clean Is Clean Enough?

Similar to the PAGs issued by DHS for late-phase recovery after an RDD or IND incident, which call for cleanup to be achieved through a "site-specific optimization process," the EPA's 2009 draft recovery strategy also applied optimization.[35] Instead of using a strict, inflexible radiation measurement to determine when it is safe to reenter a contaminated area, an "optimization" process weighs a number of factors along with health risks (eg, possible future land uses, cleanup options and approaches, technical feasibility, costs, cost-effectiveness, infrastructure, local economy, and, ultimately, public acceptance).[36] Late-phase PAGs would address the decontamination of property, which can last from months to years after an accident.

While both IND/RDD  recovery plans and draft EPA guidance for a nuclear power plant accident called for optimization, actual current U.S. regulatory policies for recovery after a nuclear accident apply a very different philosophy. Optimization, as a theory, drives recovery by balancing radiation risks against socioeconomic considerations under emergency circumstances. Current U.S. policies, such as the Comprehensive

Environmental Response, Compensation, and Liability Act (CERCLA), use more conservative, nonemergency thresholds based on the Linear No-Threshold (LNT) model,[37] which assumes that no level of ionizing radiation is safe. Such a model strives for a level of radiation that is likely to be impractical after a major accident and may be inconsistent with the public's desire to return to homes and businesses in ways that alter their risk-tolerance thresholds. The international community, namely the International Commission on Radiological Protection (ICRP), has adopted optimization and has issued implementing guidelines, which are currently under consideration by U.S. agencies.

While optimization is conceived as a process, not an explicit set of guidelines, much can be done in advance to guide the implementation of that process and enable government and community leaders to carry it out more effectively than was done in Fukushima. In keeping with that realization, DHS is supporting the development of optimization guidelines by NCRP for recovery from radiological releases due to INDs and RDDs.[37] Some state radiological managers also recommended that a "30-day toolkit" for radiological recovery be developed to facilitate state and local decision making for NPP accidents.

### Federal Organization

Responsibility for recovery is spread over several agencies, including the NRC, DHS/FEMA, EPA, and CDC. While the NRC regulates nuclear plant safety and emergency planning, DHS and FEMA would take the federal lead on response coordination with state and local authorities. DHS might also call on the DOE to deploy the Federal Radiological Monitoring and Assessment Center, which would assist in radiological monitoring in coordination with the EPA, the DOD, HHS, and the FBI.[38] Meanwhile, the EPA would be the federal lead in coordinating environmental cleanup and recovery with states and locals, and the CDC would lead population monitoring for exposure and health risk and provide laboratory support. For a domestic event, the federal response would be guided by the National Response Framework, which was published by DHS in 2008 and provides an all-hazards approach to domestic incident response.[39]

Given the importance of public health expertise in the response to a nuclear power plant accident, many project participants believed that CDC and the public health community should be prepared and resourced to have a prominent role in the response to domestic nuclear power plant accidents. Representatives from state and local governments were unclear regarding which federal agency would be responsible for providing support to states for recovery.

> *"The recovery issue is fraught with angst because there's no clear strategy or leadership on the federal side regarding funding, communication, and relocation of populations."*

Participants called for improved state and local exercises to examine critical issues related to recovery policy. One example of such an exercise was Liberty RadEx. This was a national exercise sponsored and designed by the EPA to practice and test federal, state, and local assessment and cleanup capabilities following a mock "dirty bomb" attack. Importantly, the exercise practiced late-phase responsibilities, including working with stakeholders and the public to plan for community recovery. Many of Liberty RadEx's findings echoed concerns expressed by our project's participants, including that recovery policy for wide-area contamination is inadequate and improved public communication is needed.[40]

Still, some cautioned against publicly exercising recovery, noting that doing so risks communicating to the public that reentry and recovery would be associated with even the most minor accident at their local nuclear plant. Thus, as an alternative, no-fault tabletop exercises were suggested. Such exercises would exercise recovery and could include a comprehensive gap analysis aimed at understanding where gaps exist throughout the entire statutory, regulatory, and legal framework for recovery.

### Volunteers

In Japan, volunteers included individuals decontaminating their own homes, people cleaning contaminated streets and schools, and the famous Fukushima 50—the team of workers, emergency services personnel, and scientists that volunteered to remain on-site, enduring high doses of radiation as they worked to cool fuel rods.[41] History indicates that volunteers would come forward after a major disaster in the U.S. Most recently, residents of the U.S. Gulf states volunteered to clean up following the Deepwater Horizon oil spill, only to have their services refused due to liability concerns. Fukushima may represent a watershed experience in radiological event response, as the significant role of community volunteers is becoming more evident. Accordingly, meeting participants stressed the importance of incorporating volunteers into recovery policy and drawing on trained radiation professionals from throughout the country as well as untrained volunteers from the affected area. In particular, there was a need expressed for radiation protection standards that can be clearly applied to members of the public acting in this capacity.

# Center for Biosecurity Recommendations

The following recommendations aim to provide guidance for efforts to increase resilience and protect the public following a radiological release from a commercial NPP in the U.S. They are the product of the Center's study and analysis of material derived from an extensive literature review, interviews with subject matter experts, and discussions during a daylong workshop hosted at the Center. Whereas the recommendations represent the opinions of the Center alone, it is our view that most of the recommendations would be supported by the majority of the experts who participated in this project.

## 1. The U.S. should evaluate the adequacy of current Emergency Planning Zones.

Following the Fukushima Daiichi accident, the Japanese government concluded that the country's existing framework for offsite emergency response—the Emergency Planning Zone (EPZ) structure—proved inadequate to guide evacuation decisions. Japanese officials have since reevaluated the EPZs and attendant evacuation criteria and will expand the size of planning zones to account for large-scale contamination events, with the expectation that such changes will improve timely decision making during a crisis.

In light of the Fukushima experience, the U.S. EPZ system should be carefully assessed to determine the following: Are planning zone distances sufficient to accommodate the potential radiation hazards posed by multiple units of a power plant, spent fuel storage, and the possibility of extended releases? Is the existing decision-making process during plant emergency conditions sufficiently timely and dynamic to be effective for conditions identified at Fukushima? Do we have sufficiently robust radiation measurement and modeling systems in place to monitor radiation threats in the aftermath of a large-scale accident? Would those systems still be functioning despite large-scale power loss or other disruption? Do current nuclear plant safety goals adequately reflect the socioeconomic impact of a wide-scale contamination event? Answers to these questions should guide future evaluations of U.S. EPZs.

## 2. The U.S. should improve the emergency exercise process for commercial nuclear power plants to make exercises more realistic and address a broader range of scenarios.

To maintain licensure and operations, nuclear power plants must conduct emergency response tests with documented successful outcomes. A plant that does not have satisfactory performance overall cannot continue operations. This approach over the years has yielded a clear understanding of roles and responsibilities, but it has also led to increasing conformity and rote in exercises. To be fully effective, emergency exercises need to challenge participants with both expected and unexpected scenarios, including ones that may involve protracted releases and longer-term response. Currently, due to regulatory consequences, domestic commercial nuclear power plants are unable to exercise to failure. No-fault tabletop exercises should become part of the exercise process. Other good options to increase preparedness include regional exercises (eg, Liberty RadEx) that can accommodate a number of agencies and states on a periodic basis.

## 3. U.S. federal policy should downplay use of KI and emphasize evacuation.

Potassium iodide (KI) is an over-the-counter medical countermeasure that can diminish the uptake of radioactive iodine by the thyroid gland and prevent thyroid cancer in children and developing fetuses. That KI has no value in protecting adults from cancer is well known by professionals and backed by scientific data.

U.S. federal policy recommends that states consider stockpiling and distribution of KI as an adjunct to evacuation, which is the single most important protective measure available. Of 35 U.S. states that lie within the 10-mile EPZ of a nuclear power plant, 24 states plan to distribute KI in the event of an accident, and 9 do not. Those states that do plan to distribute KI will issue blanket orders for administration once the low pediatric radiation threshold has been reached (>5 cGy) during an emergency.

A major concern is that KI instills a false sense of security among the population and that demand for KI might delay evacuation. For states that have already committed to KI distribution, it would be extremely difficult to move away from that position without a substantial investment in public education. The experience with Fukushima provided some foreshadowing of possible U.S. demand for KI: As the plume of radioisotopes released from the Japanese power plant blew across the Pacific, the demand for KI by fearful U.S. West coast residents skyrocketed despite the lack of any evidence of any health threat or possible KI benefit. Given the likelihood that plans to provide (or predistribute KI) in the event of a nuclear accident will continue, it is paramount that the most important emergency response message is always: "Evacuate first—do not waste precious time looking for KI or waiting for it."

### 4. The U.S. government should expand preevent education and improve postevent communication.

Ionizing radiation ranks near the top of the public's list of most feared threats. When a mass radiation event occurs, the public fear factor and low baseline knowledge about radiation creates a major communications challenge. Federal communication efforts are further complicated by the need to coordinate information and messages from many agencies. The CDC, DOE, EPA, FEMA, HHS, the NRC, and the White House were all included in the domestic response to the Fukushima accident. In contrast to the nuclear power plant accidents at Three Mile Island and Chernobyl, the Fukushima Daiichi accident has highlighted the new challenges of communicating with the public in the "information era" of 24-hour news cycles and social media outlets.

In the absence of consistent, trustworthy messaging from government authorities, members of the public may act in ways that put them in harm's way. Without guidance from the government, residents of the town of Namie in Fukushima prefecture evacuated north, into the plume, believing that the winter winds would be blowing south. In later phases of the accident, the Japanese government struggled to communicate the relative risks of radiation exposure as residents of contaminated areas returned to their properties. Radiation education has since become a part of elementary education; the Japanese government has distributed textbooks to schools throughout the affected region.

Moving forward, community resilience to radiological threats in the U.S. would benefit from preevent education and postevent communication efforts that provide straightforward and actionable protective advice to the public. Public communication efforts must use all available media outlets and remain consistent across all levels of government—federal, state, and local. Ongoing federal agency efforts to understand how to educate the public before and during a crisis are important and should be supported. Furthermore, a nuclear power plant accident and a subsequent radiological release is both a technological and public health disaster. Given public concerns about the health effects of ionizing radiation, it seems important to include a health expert in the federal messaging approach alongside a nuclear regulatory official. In the future, it would be wise for the NRC and the CDC to consider jointly addressing the public about the threats posed by a compromised nuclear power plant and its public health consequences.

### 5. The U.S. should articulate a clear plan for recovery after a large-scale accident.

The chief focus of emergency preparedness and response for commercial nuclear power plants has been on the immediate and near-term response to off-normal events and the prevention and mitigation of "design basis accidents." This partly stems from a reasoned allocation of finite resources according to risk probability and partly from the unwanted stigmatization that comes with broaching extreme, albeit improbable, consequences in a volatile public arena. However, the modern "defense-in-depth" design and operation of the Fukushima Daiichi plants were overcome by an external environmental disaster, not compromised, as at Chernobyl, by vulnerable design and misguided operations. The Japanese had not taken into account a low-probability, high-consequence event that would release radioactivity on the scale experienced in March 2011. The "unlikelihood" of such an accident itself militated against steps that could have been taken to make recovery more manageable. With a late-phase protective action guide pending for the past 20 years, and little planning and exercising being conducted for the recovery phase, a serious gap exists in U.S. recovery planning following a nuclear power plant accident. The consequences of continued inaction could be misdirection, delays, and confusion, as has been demonstrated in Japan, where the public struggles to recover lives and livelihoods. The U.S. government should publish a late-phase PAG to guide recovery planning and response, articulate its approach for recovering from a major radiological release, and develop guidance to aid state and local authorities in dealing with their responsibilities for mitigating exposure, managing decontamination and cleanup, and resettling displaced populations. This emerging set of benchmarks needs to be exercised periodically in a manner that does not detract from current emergency preparedness obligations at nuclear power plants.

### 6. The U.S. should take steps to sustain professional radiological expertise in the public sector.

With few new nuclear power plant reactors coming online in the U.S and a gradual decline in the influx of nuclear health physicists, a generational turnover in radiological safety and health professionals is leading to shortages across government and in the private sector. The commercial nuclear utilities have responded by subsidizing college academic programs to ensure a steady supply of expertise. However, the public sector continues to struggle with retirements and competition from the medical testing and imaging sector, which can offer higher compensation. A number of actions can be taken to ensure a sustained supply of this essential expertise for federal and local governments. First, the federal government once offered graduate school grants and traineeships to encourage entry by nuclear safety and health physics graduates into the public sector. This effort could be reinstated with relative ease and with little budgetary burden. Second, existing resources can be leveraged better to provide support where needed and, in a major emergency, shared across agencies and between geographical areas. This is already being accomplished at the state and local levels, for example, by the Conference of Radiation Control Program Directors, a nongovernmental professional organization dedicated to radiation protection, and the U.S. Public Health Service, which has been identifying those with radiation expertise among its ranks and developing the capability to formulate "strike teams" that could be employed during a radiation emergency. Finally, a means should be created to convey the experience possessed by the existing cadre of radiological response professionals through a mentoring program or other participatory means by which their knowledge can be captured for their successors.

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